

Garlic

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Scientific Name and Introduction: Garlic, *Allium sativum* L., is a member of the onion family (Alliaceae). It is a bulb comprised of cloves (thickened storage leaves) individually wrapped in dried leaf sheaths or skins attached to a compressed stem plate. The whole bulb is also wrapped in several layers of dried leaf sheaths. In the U.S. garlic is grown mostly in California and neighboring states. Garlic is imported principally from Argentina, Chile, China, and Mexico. Garlic is produced as an annual crop for seed, fresh market, and processed (dried) products.

Quality Characteristics and Criteria: High quality garlic bulbs are clean, white (or other color typical of the variety), and well cured (dried neck and outer skins). The cloves should be firm to the touch. Cloves from mature bulbs should have a high dry weight and SSC, > 35% in both cases.

Horticultural Maturity Indices: Garlic can be harvested at different stages of development for specialty markets, but most garlic is harvested when the bulbs are mature. Harvest occurs after the tops have fallen and are dried.

Grades, Sizes and Packaging: Grades include U.S. No. 1 and unclassified, and are based primarily on external appearance and freedom from defects. Minimum diameter for fresh market is 6 mm (1.5 in). Garlic is usually packed loose in 2.3, 4.6, 10, and 13.6 kg (5, 10, 22, and 30 lb) cartons, and may also be packed in smaller weight net bags or trays for retail.

Cooling: Well cured garlic has a very low respiration rate and it is typically cooled when placed in storage. High initial airflow may be used to bring pulp temperature down rapidly to storage temperature.

Optimum Storage Conditions: The variety of garlic affects potential storage-life, and the recommended conditions for commercial storage depend on the expected storage period. Garlic can be kept in good condition for 1 to 2 mo at ambient temperatures of 20 to 30 °C (68 to 86 °F) under low RH, ie., < 75% (Hardenburg et al., 1986). However, under these conditions, bulbs will eventually become soft, spongy and shriveled due to water loss. For long-term storage, garlic is best maintained at temperatures of -1 to 0 °C (30 to 32 °F) with low RH (60 to 70%). Good airflow throughout the vented bins or other storage containers is necessary to prevent any moisture accumulation. Under these conditions garlic can be stored for more than 9 mo. Garlic is also held in common storage for 3 to 4 mo if temperatures are kept cool (cool night air ventilation), with good airflow and at low RH. Garlic will eventually lose dormancy, signaled by internal development of the sprout. This occurs most rapidly at intermediate storage temperatures of 5 to 18 °C (41 to 64.4 °F) (Mann and Lewis, 1956; Hardenburg et al., 1986). For long-term storage, garlic should have no or minimal internal sprout growth and should be well cured (see “Special Considerations” section). To control sprout development and lengthen the storage period, garlic may be treated with pre-harvest applications of sprout inhibitors, such as maleic hydrazide, or be irradiated after harvest (Hardenburg et al., 1986). Garlic odor is easily transferred to other products, so they should be stored separately. High RH in storage will favor mold growth and rooting. Mold growth can also be problematic if garlic has not been well cured before storing.

Controlled Atmosphere (CA) Considerations: Atmospheres with high CO₂ (5 to 15%) are beneficial in retarding sprout development and decay during storage at 0 to 5 °C (32 to 41 °F). Low O₂ alone (0.5%) does

not retard sprout development of ‘California Late’ stored up to 6 mo at 0 °C (32 °F). Atmospheres with 15% CO₂ may produce a yellow translucent discoloration on some cloves after about 6 mo (Cantwell, unpublished).

Retail Outlet Display Considerations: Garlic should be kept cool and dry.

Chilling Sensitivity: Garlic is not chilling sensitive and optimum storage temperature of -1 °C (30 °F) is just above the freezing point of garlic.

Ethylene Production and Sensitivity: Garlic produce only very low amounts of ethylene and are not particularly sensitive to ethylene exposure.

Respiration Rates:

Temperature	Intact Bulbs	Fresh-peeled Cloves
	(mg CO ₂ kg ⁻¹ h ⁻¹)	
0 °C	4 to 12	24
5 °C	8 to 24	30 to 40
10 °C	12 to 36	70 to 100
15 °C	14 to 30	
20 °C	14 to 26	

To get mL kg⁻¹ h⁻¹, divide the mg kg⁻¹ h⁻¹ rate by 2.0 at 0 °C (32 °F), 1.9 at 10 °C (50 °F), and 1.8 at 20 °C (68 °F). To calculate heat production, multiply mg kg⁻¹ h⁻¹ by 220 to get BTU per ton per day or by 61 to get kcal per metric ton per day. Data modified from Hardenburg et al. (1986) with data for intact and fresh peeled cloves from Cantwell (2000). Respiration rates increase when sprouting begins.

Physiological Disorders: Waxy breakdown is a physiological disorder that affects garlic during latter stages of growth and is often associated with periods of high temperature near harvest. Early symptoms are small, light yellow areas in the clove flesh that darken to yellow or amber. Later, the clove becomes translucent, sticky and waxy, but the outer dry skins are not usually affected. Waxy breakdown is commonly found in stored and shipped garlic - rarely in the field. In addition to its association with high pre-harvest temperatures and sunscald, low O₂ and inadequate ventilation during handling and storage may also contribute.

Postharvest Pathology: Penicillium rots (*Penicillium corymbiferum* and other spp.) are common problems in stored garlic. Affected garlic bulbs may show little external evidence until decay is advanced. Affected bulbs are light in weight and individual cloves are soft, spongy and powdery dry. In an advanced stage of decay, the cloves break down in a green or gray powdery mass. Low RH in storage retards rot development. Less common storage decay problems include Fusarium basal rot (*Fusarium oxysporum cepae*) that infects the stem plate and causes shattering of cloves, dry rot due to *Botrytis allii*, and bacterial rots (*Erwinia* spp., *Pseudomonas* spp.).

Quarantine Issues: None.

Suitability as Fresh-cut Product: Whole peeled garlic cloves are a popular convenience product processed originally for foodservice but now found in retail food stores. The fresh peeled cloves are packed in rigid clear plastic containers or in plastic film liners in carton boxes. The mechanical peeling process results in broken and damaged pieces, and damage is the major factor leading to decay and quality loss during storage. Storage at 0 to 5 °C (32 to 41 °F) is imperative to maintain good quality. A 2 to 3 week storage-life is expected if kept at 5 °C (41 °F) or below. Storage temperatures above 5 °C (41 °F) will result

in pink and brown discoloration on the damaged areas, and favor root and sprout development.

Special Considerations: Outer cloves of bulbs are easily damaged during mechanical harvest and these damaged areas discolor and decay during storage. Therefore high quality garlic for the fresh market is usually harvested manually (pulled and trimmed) to avoid mechanical damage.

Curing garlic is the process by which the outer leaf sheaths and neck tissues of the bulb are dried. Warm temperatures, low RH, and good airflow are conditions needed for efficient curing. Under favorable climatic conditions in California, garlic is usually cured in the field. After harvest and trimming it may remain in bins in the field to cure further. Curing is essential to obtain maximize storage-life and have minimal decay.

Garlic flavor is due to the formation of organosulfur compounds when the main odorless precursor alliin is converted by the enzyme alliinase. This occurs at low rates unless the garlic cloves are crushed or damaged. The main compound formed by this reaction is a thiosulfinate, allicin, and is the compound responsible for the characteristic odor and flavor of fresh garlic. Allicin is also an important compound since it decomposes to other sulfur containing molecules that have purported human health benefits. Alliin content decreases during storage of garlic bulbs, but the effect of time, storage temperatures and atmospheres has not yet been well documented.

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